

Reasonable Potential Issue Paper: Determining when California Ocean Plan Water Quality-based Effluent Limitations are Required

Steven G. Saiz, Environmental Scientist
Ocean Standards Unit
Standards Development Section
Division of Water Quality
State Water Resources Control Board

October 22, 2004

Outline

- I. Summary of Proposed California Ocean Plan Amendment**
- II. Present California Ocean Plan**
- III. Issue Description**
 - A. Regulatory Background
 - 1. California Ocean Plan
 - 2. NPDES Federal Regulations
 - 3. California Water Code
 - B. Statistical Procedures to Determine the Need for an Effluent Limitation
 - 1. U. S. Environmental Protection Agency's (USEPA) Technical Support Document (TSD) Reasonable Potential Procedure
 - 2. USEPA's Great Lakes Reasonable Potential Procedure
 - 3. Ohio's Reasonable Potential Procedure
 - 4. Colorado's Reasonable Potential Procedure
 - 5. Procedures Using a Statistical Confidence Interval for a Distribution Percentile
 - a. *Parametric Normal Assumption*
 - b. *Parametric Lognormal Assumption*
 - c. *Nonparametric Tolerance Interval Procedure*
 - 6. Nonparametric Procedure with Decision Error Balancing
 - 7. Censored Data Statistical Considerations
 - 8. Comparison of Reasonable Potential Procedures
 - C. Determining the Need for an Effluent Limitation with Insufficient Monitoring Data
- IV. Alternatives for Board Action and Staff Recommendations**
- V. Environmental Impact Analyses**
- VI. Compliance with Section 13421 of the California Water Code**
- VII. Proposed California Ocean Plan Amendment**
- VIII. Tables**
- IX. References**

I. Summary of Proposed California Ocean Plan Amendment

Remove existing language that allows dischargers to certify that Table B pollutants are not present in their effluent *in lieu* of monitoring, and add general "reasonable potential" language to Chapter III (Program of Implementation) of the California Ocean Plan. Additional reasonable potential procedures will be added in the new Appendix VI of the California Ocean Plan.

II. Present California Ocean Plan

Dischargers are currently allowed to certify that Table B pollutants are not present in their effluent *in lieu* of monitoring. The California Ocean Plan does not currently contain language for determining which Table B pollutants should be translated into numeric effluent limits.

III. Issue Description

A. Regulatory Background

1. California Ocean Plan

Table B of the 2001 California Ocean Plan contains numeric water quality objectives for the protection of beneficial uses in receiving waters. These water quality objectives are used to derive effluent limitations in National Pollutant Discharge Elimination System (NPDES) permits.

The California Ocean Plan also contains Implementation Provisions in Chapter III for the management of wastes discharged to the ocean. The following paragraph G2 appears on p. 21 of the California Ocean Plan (SWRCB 2001) under the Monitoring Program:

Where the Regional Board is satisfied that any substance(s) of Table B will not significantly occur in a discharger's effluent, the Regional Board may elect not to require monitoring for such substance(s), provided the discharger submits periodic certification that such substance(s) is not added to the waste stream, and that no change has occurred in activities that could cause such substance(s) to be present in the waste stream. Such election does not relieve the discharger from the requirement to meet the objectives of Table B.

This language first appeared in the 1983 California Ocean Plan (SWRCB 1983). The Final Environmental Impact Report (EIR) for the 1983 California Ocean Plan (Volume 1, Section II, p. 31-32) explained the rationale for the addition (SWRCB 1983). Comments received in 1983 expressed the view that "there should be a mechanism in the Ocean Plan for reducing or removing limits and monitoring requirements when the discharger either does not discharge a substance or consistently meets Table B requirements." The EIR explains further that "allowing dischargers relief in these instances would reduce unnecessary monitoring costs." This 1983 addition to the California Ocean Plan was expected to reduce monitoring requirements for such dischargers as marine aquaria or aquaculture operations and was "not expected to apply to municipal dischargers."

The underlying motive for this language, therefore, was to reduce monitoring costs when discharges have a high likelihood of being free of Table B pollutants. The language was not intended to allow the removal of effluent limitations. The original comments were valid in that the California Ocean Plan, then as now, does not contain guidance for determining which Table B pollutants should be translated into numeric effluent limits.

A literal reading of the 2001 California Ocean Plan would lead one to believe that effluent limitations are required for all Table B pollutants. Indeed, many existing ocean discharge permits routinely contain effluent limits for *every* pollutant listed in Table B. For example, p. 12 of the 2001 California Ocean Plan reads as follows (emphasis added):

Effluent limitations for water quality objectives listed in Table B, with the exception of acute toxicity and radioactivity, **shall** be determined through the use of the following equation:

$$C_e = C_o + D_m (C_o - C_s) \quad \text{(Equation 1)}$$

where C_e = the effluent concentration limitation in $\mu\text{g/L}$,
 C_o = the concentration in $\mu\text{g/L}$ to be met at the completion of initial dilution (*i.e.*, the Table B Water Quality Objective),
 C_s = the background seawater concentration in $\mu\text{g/L}$ [from the Ocean Plan Table C],
 D_m = minimum probable initial dilution expressed as parts seawater per part wastewater.

Equation 1 was derived by consideration of mass balance relationships.

The periodic discharger certification effectively replaces actual analytical monitoring. Appendix III of the California Ocean Plan, however, requires periodic monitoring of Table B pollutants, the monitoring frequency being based on the discharger's flow rate.

Unfortunately, the net effect of using the 1983 "relaxation of monitoring" language is the possibility of having effluent limitations in ocean discharge permits without adequately monitoring for the regulated pollutant. The G2 certification language prevents the determination of compliance with effluent limitations as required by the Ocean Plan (Section III, C7 and Section III G1) and Federal NPDES regulations (40 CFR 122.44 (i)(1)).

Lastly, the G2 certification language precludes the determination of compliance with Table B water quality objectives through sampling of the waste field as required by the Ocean Plan (Section II, A3). The G2 certification language and the resulting lack of monitoring data makes it difficult to assess the attainability of revised Table B water quality objectives. For example, during the 2001 revision of the Ocean Plan, 2 out of 7 randomly selected NPDES facilities did not have monitoring data for 12 pollutants which

staff had recalculated water quality objectives, even though these 2 facilities were previously given effluent limitations for those 12 pollutants (SAIC 1999).

The California Ocean Plan would be amended by deleting the 1983 G2 language.

2. NPDES Federal Regulations

In contrast, NPDES Federal Regulations provide procedures for permitting authorities to determine when water quality-based effluent limitations are needed [40 Code of Federal Regulations (CFR) 122.44 (d)(1)(ii)]:

When determining whether a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric criteria within a State water quality standard, the permitting authority shall use procedures which account for existing controls on point and nonpoint sources of pollution, the variability of the pollutant or pollutant parameter in the effluent, the sensitivity of the species to toxicity testing (when evaluating whole effluent toxicity), and where appropriate, the dilution of effluent in the receiving water.

Note that water quality *criteria* in federal regulations are equivalent to water quality *objectives* in the California Ocean Plan. In addition, 40 CFR 122.44 (d)(1)(iii) reads (emphasis added):

When the permitting authority determines, using the procedures in paragraph (d)(1)(ii) of this section, that a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the allowable ambient concentration of a State numeric criteria within a State water quality standard for an individual pollutant, **the permit must contain effluent limits for that pollutant.**

Because effluent limitations are developed for those pollutants actually exceeding or having a "reasonable potential" to exceed a water quality criterion, the net effect of a reasonable potential analysis may be a reduction in the number of effluent limitations incorporated into a permit.

USEPA's promulgation of the 40 CFR 122.44 reasonable potential language was in the June 2, 1989 Federal Register (pp. 23868-23899). USEPA recognized that the permitting authority would routinely need to provide a basis for concluding that a discharge has the reasonable potential to cause excursions above a water quality criterion: Page 23873 of the June 2, 1989 Federal Register reads as follows:

Some commenters suggested that all discharges would be required to have limits under this language. EPA does not expect this will be the case. However, EPA expects that with few exceptions, all major POTWs and major industrial discharges will need to be evaluated to determine whether

they have a reasonable potential to cause excursions. Before requiring a water quality-based effluent limit, the permitting authority must have a basis for finding that discharges have the reasonable potential to cause excursions above the water quality criteria. When EPA is the permitting authority, the Technical Support Document will normally provide the basis for such a finding.

The NPDES discharger, however, is responsible for attaining, monitoring, and maintaining compliance with those effluent limitations in the NPDES permit. Under Section 308 of the Clean Water Act (CWA) dischargers are required to sample effluents and make monitoring reports to determine, in part, any violations of effluent limitations or to assist in the development of effluent limitations.

In summary, NPDES Federal Regulations require that NPDES permits contain water quality-based effluent limitations for those pollutants that cause, or may cause or contribute to, an excursion of State water quality criteria. Accordingly, effluent monitoring is required to ensure compliance with those effluent limitations given.

3. California Water Code

A recent amendment to the California Water Code includes reasonable potential language, but this language applies specifically to publicly owned treatment works (POTW). California Water Code Section 13263.6 (a) reads as follows:

13263.6 Effluent limitations

(a) The regional board shall prescribe effluent limitations as part of the waste discharge requirements of a POTW for all substances that the most recent toxic chemical release data reported to the state emergency response commission pursuant to Section 313 of the Emergency Planning and Community Right to Know Act of 1986 (42 U.S.C. Sec. 11023) indicate as discharged into the POTW, for which the state board or the regional board has established numeric water quality objectives, and has determined that the discharge is or may be discharged at a level which will cause, have the reasonable potential to cause, or contribute to, an excursion above any numeric water quality objective.

This language is similar in effect to 40 CFR 122.44 (d)(1)(iii) and reinforces the need to add similar language to the California Ocean Plan.

B. Statistical Procedures to Determine the Need for an Effluent Limitation

Various procedures are used to assist NPDES permit writers when deciding whether a water quality-based effluent limitation is needed. Conceptually, this is a yes-or-no dichotomous decision. Statistical methods of data analysis are often employed in order to produce a scientifically defensible decision. All statistical procedures, however, require representative effluent samples and an examination of the assumptions underlying the statistical model

employed. Presented below are procedures that are currently being used, or could be used, to determine the need for an effluent limitation.

1. U. S. Environmental Protection Agency's (USEPA) Technical Support Document (TSD) Reasonable Potential Procedure

In 1991, the USEPA published the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991). This document, abbreviated as TSD, contains guidance for characterizing an effluent discharge and for conducting a reasonable potential analysis (TSD, Chapter 3, Effluent Characterization). USEPA developed this statistical approach to characterize effluent variability and reduce uncertainty when deciding whether to require an effluent limit:

EPA recommends finding that a permittee has "reasonable potential" to exceed a receiving water quality standard if it cannot be demonstrated with a high confidence level that the upper bound of the lognormal distribution of effluent concentrations is below the receiving water criteria at specified low-flow conditions (TSD Box 3-2, p.53).

The TSD procedure estimates an upper one-sided confidence bound for an upper percentile of the pollutant distribution under a lognormal distribution assumption.

The TSD procedure multiplies an order statistic $X_{(n)}$, the maximum observed sample value, by a reasonable potential multiplying factor k . USEPA derived these multiplying factors by consideration, initially, of non-parametric tolerance interval theory (Murphy 1948), then subsequently applying the non-parametric theory to a parametric lognormal model (Aitchison and Brown 1957). The TSD procedure, thus, produces a semi-parametric one-sided upper c 100 percent confidence bound for the p 100th percentile:

$$\text{TSD}_{(c, p)} = X_{(n)} k_{(c, p, n, \sigma_L)},$$

where $X_{(n)}$ is the observed sample maximum and $k_{(c, p, n, \sigma_L)}$ is the reasonable potential multiplying factor for the 100 p th percentile calculated with c 100 percent confidence for n samples randomly drawn from a lognormal distribution with shape parameter σ_L .

USEPA reasonable potential multiplying factors are calculated using the following equation:

$$k_{(c, p, n, \sigma_L)} = \exp(\sigma_L \{ \Phi^{-1}[p] - \Phi^{-1}[(1-c)^{1/n}] \}),$$

Where, σ_L is the lognormal distribution shape parameter, $\Phi^{-1}[\]$ indicates the Z-score obtained from a percentile of the standard normal distribution (for example, $\Phi^{-1}[0.95] = 1.645$), and n is the sample size. The quantity $f_n = \{ \Phi^{-1}[0.95] - \Phi^{-1}[(1-0.95)^{1/n}] \}$ is less than zero for $n > 59$ and is tabulated in Table 1 for $1 \leq n \leq 35$.

A "method of moments" estimate of the shape parameter σ_L is obtained by using the sample standard deviation divided by the sample arithmetic mean to find the sample coefficient of variation CV and applying the following equation (Aitchison and Brown 1957):

$$\sigma_L = \sqrt{\ln(CV^2 + 1)}.$$

The TSD procedure does not require a minimum sample size, but for small data sets ($n \leq 9$) USEPA advises to use a default CV value of 0.6 which corresponds to $\sigma_L = 0.5545$. This allows upper bound estimates with as little as one effluent measurement!

Two tables of Reasonable Potential Multiplying Factors are given in the TSD: the 99 percent confidence level with 99 percent probability basis and the 95 percent confidence level with 95 percent probability basis. For example $k_{(.95, .95, 10, 0.5545)} = 1.7$. The guidance allows for other probability basis percentiles to be selected by regulatory agencies but is silent on other acceptable upper confidence levels.

If the discharger is allowed a mixing zone, then the upper bound effluent concentration is adjusted to the upper bound concentration expected at the edge of the mixing zone after complete mixing. Solving the mass balance Equation 1 for C_o produces an estimate of the effluent concentration after mixing. An effluent limitation is required if the upper bound concentration, upon complete mixing, is greater than the water quality objective.

An example of effluent limitations established using the TSD reasonable potential procedure is the 1996 City of San Francisco Westside wastewater treatment plant NPDES permit (City and County of San Francisco 1996).

2. USEPA's Great Lakes Reasonable Potential Procedure

In 1995, the USEPA promulgated the Final Water Quality Guidance for the Great Lakes System (GLS) in the Federal Register (USEPA 1995). This guidance was added to the Code of Federal Regulations at 40 CFR Part 132. The GLS reasonable potential procedure, Procedure 5, is found in Appendix F of the GLS and is very similar to the reasonable potential procedures found in the TSD. The *projected effluent quality* is specified as...

the 95 percent confidence level of the 95th percentile based on a lognormal distribution or the maximum observed effluent concentration, whichever is greater.

Alternatively, the permit writer may define the *projected effluent quality* as...

the 95th percentile of the distribution of the projected population of daily [weekly or monthly] values of the facility-specific effluent monitoring data projected using a scientifically defensible statistical method that accounts for

and captures the long-term daily [weekly or monthly] variability of the effluent quality, accounts for limitations associated with sparse data sets and, unless otherwise shown by the effluent data set, assumes a lognormal distribution of the facility-specific effluent data.

The GLS also requires the calculation of a *preliminary effluent limitation*, which incorporates the water quality criterion, effluent dilution, and background pollutant concentrations. Mixing zones for bioaccumulative chemicals are not allowed for some GLS dischargers.

A water quality-based effluent limitation is required if the *projected effluent quality* exceeds the *preliminary effluent limitation*.

3. Ohio's Reasonable Potential Procedure

The alternative GLS reasonable potential definition above allows Great Lakes States more flexibility when determining the need for effluent limits. For example, the State of Ohio has recommended comparing the *projected effluent quality* with 75 percent of the *preliminary effluent limitation*. This revised definition results in a reasonable potential procedure that is more protective than the GLS and was thought to provide a necessary buffer against inaccurate reasonable potential determinations (Ohio 1996).

4. Colorado's Reasonable Potential Procedure

The State of Colorado recently issued guidance for determining reasonable potential (Colorado 2003). Colorado's procedure is similar to the USEPA TSD procedure. The 99th percentile of the effluent distribution (calculated with 99 percent confidence) or the sample maximum, whichever is higher, is compared to the numeric water quality criterion.

At least ten effluent samples collected over a period of one year are required for reasonable potential assessments. Finally, the procedure provides guidance for estimating the effluent variability when some of the observations are below the analytical detection limit or suspected of being statistical outliers.

5. Procedures Using a Statistical Confidence Interval for a Distribution Percentile

In certain regulatory situations, a one-sided, upper confidence bound on an upper percentile is used to compare a set of environmental samples to a fixed regulatory standard (Gibbons and Coleman 2001, Chapter 19, *Corrective Action Monitoring*). When applied to a reasonable potential analysis, the null hypothesis is that the true upper percentile is greater than or equal to the water quality objective. We reject this null hypothesis if sufficient evidence is provided through the discharger's pollutant monitoring program; in other words, we reject the null hypothesis if the one-sided, upper confidence bound on the upper percentile is below the water quality objective. If we cannot reject this null hypothesis then we conclude that the pollutant discharge has the

reasonable potential to exceed the water quality objective and an effluent limitation is required.

All of the above procedures are similar in that they use the maximum observed sample value and a reasonable potential multiplying factor k . Standard statistical methods, however, are readily available to estimate the upper percentile of a statistical distribution with a given high level of confidence; statisticians call this a *tolerance interval* and the resulting estimate is called an *upper confidence bound*, UCB (Hahn and Meeker 1991; Gibbons and Coleman 2001). Upper confidence bounds can be calculated for data believed to come from a normal distribution, a lognormal distribution, or any distribution (*i.e.*, a distribution-free tolerance interval).

a. Parametric Normal Assumption

Hahn and Meeker (1991) tabulated parametric normal tolerance factors for the construction of an Upper Confidence Bound for a population percentile when the data are Normally distributed:

$$UCBN_{(c,p)} = M + S g'_{(c,p,n)},$$

where, M is the sample mean, S is the sample standard deviation and g' is the normal tolerance factor for the one-sided upper c 100 percent confidence bound of the p 100th percentile for a sample of size n . Table 2 lists 95 percent tolerance factors obtained from Hahn and Meeker (1991, Table 12d, p.315) for the 95th percentile.

This statistical confidence interval for percentiles accounts for long-term variability; highly variable data produce a larger upper confidence bound. In addition, this method produces larger confidence bounds when increased uncertainty is present due to small sample sizes (sparse data sets). As the sample size increases the upper confidence bound decreases and ultimately converges on the true population percentile.

b. Parametric Lognormal Assumption

The same normal tolerance factors can be applied to lognormal distributions by a logarithmic transformation of the effluent data. Ott (1990) demonstrated that lognormal distributions of concentrations of environmental pollutants can arise naturally from certain physical processes, especially after a series of independent random dilutions. Along these lines, USEPA suggests that "a lognormal distribution is generally more appropriate as a default statistical model than the normal distribution" (USEPA 1992, p.2).

The Upper Confidence Bound for a population percentile when the data are Lognormally distributed (Gibbons and Coleman 2001, p.244) is obtained from the following equation:

$$UCBL_{(c,p)} = \exp(M_L + S_L g'_{(c,p,n)}),$$

where, M_L and S_L are the mean and standard deviation of the natural logarithm transformed data, respectively (i.e., maximum likelihood estimates), and g' is the normal tolerance factor for the one-sided upper c 100 percent confidence bound of the p 100th percentile for a sample of size n (Table 2).

A minimum sample size of two is required to construct confidence intervals on a percentile of a normal or lognormal distribution.

c. Nonparametric Tolerance Interval Procedure

In situations where no assumption can be made about the effluent distribution, non-parametric methods are available to construct confidence intervals on the upper percentile of any continuous statistical distribution (Hahn and Meeker 1991, Sec. 5.3.3). These non-parametric estimates of a percentile are based on the larger observed values (i.e., order statistics) in the data set and generally require a large number of observations when estimating extreme percentiles with high confidence levels.

For example, at least 59 samples are required in order to construct the upper 95 percent confidence bound on the 95th percentile of a distribution. In other words, the largest observation in a random sample of 59 observations is a nonparametric estimate of the upper 95% confidence bound for the 95th percentile. This non-parametric interval, based on the binomial probability distribution, is equivalent to a *fixed alpha* hypothesis test because the alpha error, although varying with sample size, is always at or below the nominal desired value of 5%. Some texts call this a Quantile test or, when testing the 50th percentile, a Sign Test.

Alpha errors, in this context, are defined as the probability of incorrectly rejecting the null hypothesis, thereby failing to conclude that a reasonable potential exists. In contrast, beta errors are committed when the regulatory authority fails to reject a false null hypothesis, thereby concluding that a reasonable potential exists when this conclusion is unwarranted. Both alpha and beta errors are undesirable, but a fixed alpha test only controls the alpha error rate.

6. Nonparametric Procedure with Decision Error Balancing

A non-parametric binomial distribution approach that seeks a balance between alpha and beta statistical decision making errors is possible (Lehmann 1958, Mapstone 1995, Saiz 2004a). This approach was applied in the recent SWRCB policy for CWA Section 303(d) listing (SWRCB 2004) and uses a simple count of the number of exceedances of the water quality objective in a random sample of sufficient size. The statistical error probabilities associated with the regulatory decision to remove a water segment from the Section 303(d) list for toxicants are directly analogous to a reasonable potential decision.

If the tested null hypothesis is that the actual exceedance proportion is greater than or equal to 18% and the alternative hypothesis is that the actual exceedance proportion is less than 3%, then at least 16 samples are required to keep both alpha and beta decision

errors below 20%. The absolute difference between alpha and beta error rates $|\alpha - \beta|$ is minimized while $\alpha \leq 0.2$ and $\beta \leq 0.2$, where $\alpha = \text{Excel® Function BINOMDIST}(k, n, 0.18, \text{TRUE})$, $\beta = \text{Excel® Function BINOMDIST}(n-k-1, n, 1-0.03, \text{TRUE})$ and k = the number of exceedances required to reject the null hypothesis.

This non-parametric balanced error approach allows a reasonable potential decision to be made without calculating summary statistics and without assuming a particular parametric distribution: any effluent sample of 16 or more observations having one or more exceedance of the water quality objective is sufficient evidence to demonstrate a reasonable potential (with at least 80% confidence) to cause an excursion of the water quality standard. Similarly, a sample of 16 or more observations having no exceedances of the water quality objective is sufficient evidence to demonstrate (with at least 80% confidence) that no reasonable potential exists to cause an excursion of the standard.

For sample sizes below 16, no definitive reasonable potential decision can be made using this approach because the confidence level is below 80%. However, any exceedance of a water quality objective, regardless of sample size, can be a basis to determine that the discharge causes or contributes to an excursion of the water quality standard.

7. Censored Data Statistical Considerations

Any reasonable potential analysis will be complicated by the presence of monitoring data below the analytical detection or quantification limit. Helsel (2004) and Gibbons and Coleman (2001) presented extensive reviews of statistical techniques useful for analyzing environmental data that include results not completely quantified. Such data are *censored* by a limit of detection or by a limit of quantification, or both, usually on the left tail of the population distribution.

Sample results below the limit of detection (*i.e.*, the USEPA Method Detection Limit) are *non-detects* (ND). Monitoring samples at or above the limit of detection but below the limit of quantification (*i.e.*, the California Ocean Plan Minimum Level) are *detected but not quantified* (DNQ). Various combinations of data types (NDs, DNQs, or quantified) are theoretically possible depending on the effluent distribution, the limit of detection, and the limit of quantification.

Gibbons and Coleman suggest applying Cohen's Maximum Likelihood Estimator, MLE (Cohen 1961) for censored data sets. Cohen's MLE technique adjusts the uncensored sample mean and uncensored sample standard deviation by a factor derived from the proportion of NDs below a single censoring point. Cohen (1961) provided a lookup table for the appropriate factor. Cohen's MLE "appears to work best for small normally distributed samples, and lognormal versions of the estimator can be obtained simply by taking natural logarithms of the data and censoring point" (Gibbons and Coleman 2001). Cohen's MLE is also recommended by the USEPA when 15 - 50 percent of the samples are censored (USEPA 1992; USEPA 1998). Use of Cohen's MLE requires at least two quantified sample measurements (Gibbons and Coleman 2001, Sec 13.4). Modern

statistical software allows accurate MLE for censored data without the use of a lookup table and can account for multiple censoring points (Helsel 2004).

The TSD presented a *delta lognormal* technique to account for effluent data censored by a single detection limit (USEPA 1991, Appendix E). Hinton (1993) concluded, however, that this technique vastly overestimates the mean compared to Cohen's MLE technique, especially when censoring is >60 percent.

Recent water quality data simulations by Shumway *et al.* (2002) indicate that the *Regression on Order Statistics* technique (ROS) of Helsel and Gilliom (1986) is robust, unbiased, and has a smaller variance than the MLE technique under the lognormal distribution.

The majority of censored data statistical techniques assume that only one detection limit or censoring level is present in the data; however, effluent data often contain several analytical detection limit thresholds within the same data set. A refinement of the ROS technique is available for water quality data having multiple detection limits or censoring levels (Helsel and Cohn 1988). This robust ROS method is the recommended technique of choice for estimating summary statistics for censored environmental data, especially for smaller sample sizes ($n < 50$) with more than 50% censoring (Helsel 2004). The robust ROS technique is most reliably used with at least three measured (uncensored) data values and no more than 80 percent censoring (D. Helsel, personal communication to S. Saiz, email of 10/11/04.)

With highly censored data (>80 percent censored) or completely (100 percent) censored data, a non-parametric binomial distribution statistical method can often still be used to compare a data set of sufficient size to a water quality criterion. Each observation in the data set is individually compared to the criterion. Any quantified value greater than the criterion counts as an exceedance. ND results are not counted as an exceedance when the limit of detection is at or below the water quality criterion. If the limit of detection is above the water quality criterion then the sample is considered to be tie, neither exceeding nor not exceeding the criterion. The usual recommendation in non-parametric statistical tests is to ignore ties and reduce the sample size accordingly (Gibbons 1976, p108).

In a similar manner, DNQ results are not counted as an exceedance when the limit of quantification (i.e., the Minimum Level) is at or below the water quality criterion. DNQ results having a limit of quantification greater than the criterion and a limit of detection at or below the criterion is considered to be a tie. DNQ results having both the limit of detection and the limit of quantification above the criterion counts as an exceedance. If the sample size is reduced, because of extensive ties, to less than 16 samples, then no definitive reasonable potential decision can be made using this approach because the confidence level is below 80% (i.e., an inconclusive RP analysis, see Section 6 above).

8. Comparison of Reasonable Potential Procedures

SWRCB staff developed a set of criteria for comparing reasonable potential procedures by adopting essential elements from the NPDES Federal Regulations and desirable elements from other State's reasonable potential procedures. Table 3 compares the TSD procedure with the lognormal tolerance bound procedure in relation to these desirable criteria.

In addition, SWRCB staff examined empirical alpha and beta statistical error rates achieved through several simulations (Saiz 2004b). Uncensored effluent data was simulated from lognormal distributions and other probability distributions in order to compare the decision error rates associated with the TSD procedure and the UCBL procedure. When the lognormal distribution assumption is correct, the UCBL procedure effectively controlled the alpha error rate at or below 5.3% for sample sizes between 5 and 120. In contrast, the TSD procedure produced alpha error rates as high as 20%, especially when $n \leq 30$. In addition, the UCBL procedure is robust to misspecifications of the lognormal distribution, since the alpha level remains less than 5% when random sampling from gamma or truncated normal distributions. In contrast, the alpha error rate associated with the TSD procedure increases rapidly above 5% when 60 or more samples are obtained from a gamma or truncated normal distribution.

C. Determining the Need for an Effluent Limitation with Insufficient Monitoring Data

A scientifically defensible, statistically based, reasonable potential procedure allows an objective characterization of effluent discharges and is to be preferred. A statistical analysis of actual facility-specific monitoring data will lead to a more objective reasonable potential decision. In most cases, a minimum of two quantified samples above the limit of quantification are required to use these statistical methods.

If facility-specific monitoring data are insufficient to use the statistical procedures, then permit writers must use professional judgments similar to situations where effluent monitoring data are lacking, that is, a non-statistically-based reasonable potential decision. These situations include facilities having no effluent data or a single effluent sample or a highly censored effluent data set having two or less quantified samples, thereby precluding the use of censored data statistical techniques.

In the absence of facility-specific monitoring data or if insufficient facility-specific monitoring data exists to use statistical procedures, the permit writer must provide adequate justification for any effluent limits included in the permit. The TSD lists several factors to consider in addition to effluent monitoring data when determining whether a discharge causes, has the reasonable potential to cause, or contributes to an excursion of a State water quality criterion. These factors include facility dilution, type of industry or publicly-owned treatment works (POTW), other existing data (including the NPDES application), history of compliance, and type of receiving water.

If the permit writer is unable to decide whether the discharge would exceed the water quality criterion, i.e., an inconclusive RPA, the TSD recommends that whole effluent toxicity testing

or additional chemical-specific testing be added as a permit condition. This includes 100 percent censored data sets when all limits of detection or quantification are greater than the water quality criterion

IV. Alternatives for Board Action and Staff Recommendations

Because a tolerance bound procedure more appropriately utilizes facility-specific effluent data, SWRCB staff recommend the primary use of a lognormal tolerance interval-based procedure for reasonable potential determinations rather than the TSD-based procedure. When using a parametric statistical approach, the water quality objective should be compared to the one sided, upper 95 percent confidence bound of the 95th percentile of a lognormal distribution. Furthermore, when dilution is allowed, the one-sided upper confidence bound on the upper percentile should be adjusted by the mass balance equation (Equation 1 solved for C_o) prior to comparison with the water quality objective. In addition, the monitoring data should be adjusted for the averaging period expressed by the Table B objective (e.g. six-month median, 30-day average) when possible.

SWRCB staff further recommend the Helsel and Cohn (1988) method as a general approach for accounting for censored data (ND or DNQ values) when assessing reasonable potential. This technique is also recommended in the Colorado Reasonable Potential Procedure (2003). More extreme censoring can be accommodated by using a nonparametric statistical procedure with error balancing that uses a simple count of exceedances of the water quality criterion.

Eventually, data censoring may be so severe that a statistically based decision of reasonable potential cannot be made. This may happen when the water quality objective is far below the limit of quantification or when the sample size is small. Under these conditions, the permit writer must use guidance for determining the need for an effluent limit using insufficient monitoring data (see Determining the Need for an Effluent Limitation with Insufficient Monitoring Data above).

Based on the preceeding sections and the criteria in Table 3, SWRCB staff composed the reasonable potential language in the proposed amendment. A general reasonable potential paragraph will be added to Chapter III of the California Ocean Plan. Additional clarifying language will be added to a new appendix of the California Ocean Plan. This new appendix will cover factors to consider when assessing the need for an effluent limitation, the recommended statistically-based analysis procedure, and how to account for uncertainty produced by small sample sizes and censored data values.

Staff in the Ocean Standards Unit, have simultaneously developed a computer software program (RPCalc) that will perform the statistically based reasonable potential calculations recommended and presented in this section (Saiz 2003). This reasonable potential "calculator" can be used as a tool by permit writers to easily compare an effluent data set with the California Ocean Plan Table B water quality objective using the procedures identified in the proposed amendment. The software will follow the procedures specified in the new California Ocean Plan Reasonable Potential Appendix.

V. Environmental Impact Analyses

No adverse environmental effects are expected from the proposed amendment. The amendment provides a method for determining when effluent limits are required and there is no change to the water quality objectives of the California Ocean Plan.

VI. Compliance with Section 13421 of the California Water Code

Staff is not proposing the adoption of water quality objectives; therefore, we are not required to consider Section 13241 of the California Water Code for this proposed amendment to the California Ocean Plan.

VII. Proposed California Ocean Plan Amendment

Presented below are the proposed changes to the 2001 California Ocean Plan that will result if the changes proposed in Issue 2 are approved.

1. Chapter III, G. Monitoring Program, 2, page 21, delete subsection 2 and renumber subsection 3.

G. Monitoring Program

- ~~2. Where the Regional Board is satisfied that any substance(s) of Table B will not significantly occur in a discharger's effluent, the Regional Board may elect not to require monitoring for such substance(s), provided the discharger submits periodic certification that such substance(s) is not added to the waste* stream, and that no change has occurred in activities that could cause such substance(s) to be present in the waste* stream. Such election does not relieve the discharger from the requirement to meet the objectives of Table B.~~
- ~~32.~~ The Regional Board may require monitoring of bioaccumulation of toxicants in the discharge zone. Organisms and techniques for such monitoring shall be chosen by the Regional Board on the basis of demonstrated value in waste* discharge monitoring.

2. Chapter III, C. Implementation Provisions for Table B, page 12, add new subsection 2 on reasonable potential and renumber subsequent subsections.

C. Implementation Provisions for Table B

2. If the RWQCB determines, using the procedures in Appendix VI, that a pollutant is discharged into Ocean Waters at levels which will cause, have the reasonable potential to cause, or contribute to an excursion above any Table B water quality objective, the RWQCB shall incorporate a water quality-based effluent limitation in the Waste Discharge Requirement for the discharge of that pollutant.

- ~~23.~~ Effluent limitations shall be imposed in a manner prescribed by the SWRCB such that the concentrations set forth below as water quality objectives shall not be exceeded in the receiving water upon completion of initial* dilution, except that objectives indicated for radioactivity shall apply directly to the undiluted waste* effluent.
- ~~34.~~ Calculation of Effluent Limitations
- ~~45.~~ Minimum* Levels

3. Add Appendix VI to the California Ocean Plan to provide reasonable potential analysis procedures

Appendix VI

Reasonable Potential Analysis Procedure for determining which Table B Objectives require effluent limitations

In determining the need for an effluent limitation, the RWQCB shall use all representative information to characterize the pollutant discharge using a scientifically defensible statistical method that accounts for the averaging period of the water quality objective, accounts for and captures the long-term variability of the pollutant in the effluent, accounts for limitations associated with sparse data sets, accounts for uncertainty associated with censored data sets, and (unless otherwise demonstrated) assumes a lognormal distribution of the facility-specific effluent data.

The purpose of the following procedure (see also Figure VI-1) is to provide direction to the Regional Boards for determining if a pollutant discharge causes, has the reasonable potential to cause, or contributes to an excursion above Table B water quality objectives in accordance with 40 CFR 122.44 (d)(1)(iii). The RWQCB may use an alternative approach for assessing reasonable potential such as an appropriate stochastic dilution model that incorporates both ambient and effluent variability. The permit fact sheet or statement of basis will document the justification or basis for the conclusions of the reasonable potential assessment.

Step 1: Identify C_o , the applicable water quality objective from Table B for the pollutant.

Step 2: Does information about the receiving water body or the discharge support a reasonable potential assessment (RPA) without characterizing facility-specific effluent monitoring data? If yes, go to *Step 13* to conduct an RPA based on best professional judgment (BPJ). Otherwise, proceed to *Step 3*.

Step 3: Is facility-specific effluent monitoring data available? If yes, proceed to *Step 4*. Otherwise, go to *Step 13*.

Step 4: Adjust all effluent monitoring data C_e , including censored (ND or DNQ) values to the concentration X expected after complete mixing. For Table B pollutants use $X = (C_e + D_m C_s) / (D_m + 1)$; for acute toxicity use $X = C_e / (0.1 D_m + 1)$; where D_m is the minimum probable initial dilution expressed as parts seawater per part wastewater and C_s is the background seawater concentration from Table C. For ND values, C_e is the MDL; for DNQ values C_e is the ML. Go to *Step 5*.

Step 5: Count the total number of samples n , the number of censored (ND or DNQ) values c , and the number of detected values d .

Is any *detected* pollutant concentration after complete mixing greater than C_o ? If yes, the discharge causes an excursion of C_o ; go to *Endpoint 1*. Otherwise, proceed to *Step 6*.

Step 6: Does the effluent monitoring data contain three or more detected observations ($d \geq 3$)? If yes, proceed to *Step 7* to conduct a parametric RPA. Otherwise, go to *Step 11* to conduct a nonparametric RPA.

Step 7: Conduct a parametric RPA. Assume data are lognormally distributed, unless otherwise demonstrated. Does the data consist entirely of detected values ($c/n = 0$)? If yes,

- calculate summary statistics M_L and S_L , the mean and standard deviation of the natural logarithm transformed effluent data expected after complete mixing, $\ln(X)$,
- go to *Step 9*.

Otherwise, proceed to *Step 8*.

Step 8: Is the data censored by 80% or less ($c/n \leq 0.8$)? If yes,

- calculate summary statistics M_L and S_L using the censored data analysis method of Helsel and Cohn (1988),
- go to *Step 9*.

Otherwise, go to *Step 11*.

Step 9: Calculate the UCB i.e., the one-sided, upper 95 percent confidence bound for the 95th percentile of the effluent distribution after complete mixing. For lognormal distributions, use $UCBL_{(.95,.95)} = \exp(M_L + S_L g'_{(.95,.95,n)})$, where g' is a normal tolerance factor obtained from the table below. Proceed to *Step 10*.

Step 10: Is the UCB greater than C_o ? If yes, the discharge has a reasonable potential to cause an excursion of C_o ; go to *Endpoint 1*. Otherwise, the discharge has no reasonable potential to cause an excursion of C_o ; go to *Endpoint 2*.

Step 11: Conduct a non-parametric RPA. Compare each data value X to C_o . Reduce the sample size n by 1 for each tie (i.e., inconclusive censored value result) present.

Step 12: Is the adjusted $n > 15$? If yes, the discharge has no reasonable potential to cause an excursion of C_o ; go to *Endpoint 2*. Otherwise, go to *Endpoint 3*.

Step 13: Conduct an RPA based on BPJ. Review all available information to determine if a water quality-based effluent limitation is required, notwithstanding the above analysis in *Steps 1* through *12*, to protect beneficial uses. Information that may be used includes: the facility type, the discharge type, solids loading analysis, lack of dilution, history of compliance problems, potential toxic impact of discharge, fish tissue residue data, water quality and beneficial uses of the receiving water, CWA 303(d) listing for the pollutant, the presence of endangered or threatened species or critical habitat, and other information.

Is data or other information unavailable or insufficient to determine if a water quality-based effluent limitation is required? If yes, go to *Endpoint 3*. Otherwise, go to either *Endpoint 1* or *Endpoint 2* based on BPJ.

Endpoint 1: An effluent limitation must be developed for the pollutant. Effluent monitoring for the pollutant, consistent with the monitoring frequency in Appendix III, is required.

Endpoint 2: An effluent limitation is not required for the pollutant. Appendix III effluent monitoring is not required for the pollutant; the Regional Board, however, may require occasional monitoring for the pollutant or for whole effluent toxicity as appropriate under California Water Code Section 13383.

Endpoint 3: The RPA is inconclusive. Monitoring for the pollutant or whole effluent toxicity testing, consistent with the monitoring frequency in Appendix III, is required. The permit shall include a reopener clause to allow for subsequent modification of the permit to include an effluent limitation if the monitoring establishes that the discharge causes, has the reasonable potential to cause, or contributes to an excursion above a Table B water quality objective.

Appendix VI Table: **Tolerance factors $g'_{(.95,.95,n)}$ for calculating normal distribution one-sided upper 95 percent tolerance bounds for the 95th percentile (Hahn & Meeker 1991)**

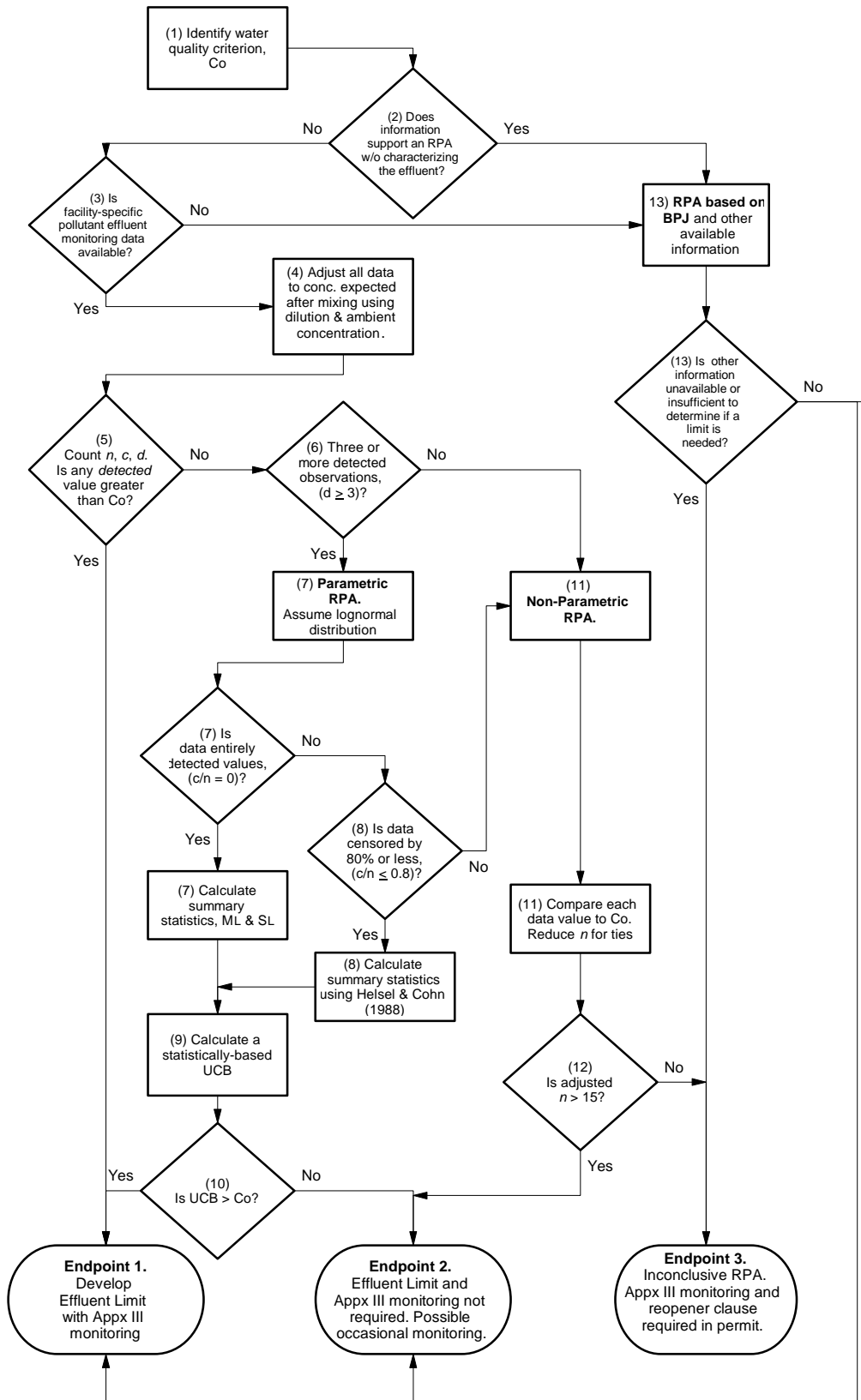
n	$g'_{(.95,.95,n)}$	n	$g'_{(.95,.95,n)}$
2	26.260	21	2.371
3	7.656	22	2.349
4	5.144	23	2.328
5	4.203	24	2.309
6	3.708	25	2.292
7	3.399	26	2.275
8	3.187	27	2.260
9	3.031	28	2.246
10	2.911	29	2.232
11	2.815	30	2.220
12	2.736	35	2.167
13	2.671	40	2.125
14	2.614	50	2.065
15	2.566	60	2.022
16	2.524	120	1.899
17	2.486	240	1.819
18	2.453	480	1.766
19	2.423	∞	1.645
20	2.396		

Appendix VI References:

Helsel D. R. and T. A. Cohn. 1988. Estimation of descriptive statistics for multiply censored water quality data. Water Resources Research, Vol 24(12):1977-2004.

Hahn J. H. and W. Q. Meeker. 1991. Statistical Intervals, A guide for practitioners. J. Wiley & Sons, NY.

Figure VI-1: Reasonable potential analysis flow chart



VIII. Tables

Table 1. USEPA TSD Reasonable Potential Procedure to calculate the upper 95 percent confidence bound for the 95th percentile of a lognormal distribution using the equation:

$$\text{TSD}_{(.95, .95)} = X_{(n)} \exp(\sigma_L f_n)$$

where, $X_{(n)}$ = maximum value of n observed samples,

σ_L = Standard Deviation for the natural logarithm transformed data

(If $n \leq 9$, use $\sigma_L = 0.5545$ for the TSD procedure)

f_n = selected from table below based on sample size.

Number of Samples, n	TSD semi-parametric lognormal procedure, $f_n = \{\Phi^{-1}[0.95] - \Phi^{-1}[(1 - 0.95)^{1/n}]\}$
1	3.290
2	2.405
3	1.981
4	1.713
5	1.521
6	1.373
7	1.255
8	1.156
9	1.071
10	0.998
11	0.933
12	0.876
13	0.824
14	0.777
15	0.733
16	0.694
17	0.657
18	0.623
19	0.591
20	0.561
21	0.532
22	0.506
23	0.480
24	0.456
25	0.434
26	0.412
27	0.391
28	0.372
29	0.353
30	0.334
31	0.317
32	0.300
33	0.284
34	0.268
35	0.253

Table 2. Tolerance factors $g'_{.95,.95,n}$ for calculating normal distribution one-sided upper 95 percent tolerance bounds for the 95th percentile (from Hahn & Meeker 1991, Table A.12d).

n	$g'_{.95,.95,n}$	n	$g'_{.95,.95,n}$
2	26.260	21	2.371
3	7.656	22	2.349
4	5.144	23	2.328
5	4.203	24	2.309
6	3.708	25	2.292
7	3.399	26	2.275
8	3.187	27	2.260
9	3.031	28	2.246
10	2.911	29	2.232
11	2.815	30	2.220
12	2.736	35	2.167
13	2.671	40	2.125
14	2.614	50	2.065
15	2.566	60	2.022
16	2.524	120	1.899
17	2.486	240	1.819
18	2.453	480	1.766
19	2.423	∞	1.645
20	2.396		

Table 3. Comparison of lognormal reasonable potential procedures in relation to desirable criteria.

Desirable Criterion	TSD Procedure, $TSD_{(c,p)}$	Lognormal Tolerance Bound Procedure, $UCBL_{(c,p)}$
Incorporates a scientifically defensible statistical method.	True. An upper percentile estimated with high confidence is compared to the Water Quality Objective. The actual confidence level is less than 95% with small sample sizes.	True. The 95 th percentile estimated with 95 percent confidence is compared to the Water Quality Objective.
Accounts for and captures the long-term variability of the pollutant in the effluent.	True for 10 or more samples. False for less than 10 samples.	True. Effluent variability is estimated from the samples for all sample sizes.
Accounts for limitations associated with censored data sets.	True, if the USEPA Delta technique is used. Delta lognormal technique assumes one censoring threshold.	True. The Helsel and Cohn (1988) technique accounts for multiple censoring thresholds and performs better than the Delta lognormal technique.
Accounts for limitations associated with sparse data sets.	True. Small data sets produce a larger upper confidence bound. Large data sets converge on the true population percentile.	True. Small data sets produce a larger upper confidence bound. Large data sets converge on the true population percentile faster than the TSD procedure.
Incorporates dilution of the effluent in the receiving water.	True.	True.
Is not unduly affected by outliers or extreme data values.	False. Sample maximum will be a prime outlier suspect.	True. Sample mean and standard deviation are derived from all data and are not unduly influenced by a single observation.
Assumes effluent data is lognormally distributed, unless otherwise shown by the data	True.	True.

IX. References

- City and County of San Francisco. 1996. Letter from Michele Plá to Terry Oda, USEPA, "Reasonable potential analysis for the Westside permit." March 27, 1996.
- Cohen, A. C. 1961. *Tables for maximum likelihood estimates: singly truncated and singly censored samples*. Technometrics 3:535-541.
- Colorado, State of. 2003. *Determination of the requirement to include water quality standards-based limits in CDPS permits based on reasonable potential: procedural guidance*. Colorado Department of Public Health and Environment, Permits Unit. <http://www.cdphe.state.co.us/wq/Permits/wqcdpmt.html#RPGuide>.
- Gibbons, R. D. and D. E. Coleman. 2001. *Statistical methods for detection and quantification of environmental contamination*. J. Wiley & Sons. New York. [See especially sec. 19.7.2, Lognormal confidence limits for a percentile.]
- Hahn, G. J. and W. Q. Meeker. 1991. *Statistical intervals: a guide for practitioners*. J. Wiley & Sons, New York. [See especially sec. 4.4, Confidence interval for a percentile of a normal distribution and Tables A12a-d, Factors $g'_{(1-\alpha, p, n)}$ for calculating normal distribution one-sided $100(1-\alpha)$ tolerance bounds; sec 5.2.3 One-sided distribution-free confidence bounds for a percentile.]
- Helsel, D. R. 2004. *Non-detects and data analysis*. J. Wiley & Sons. New York.
- Helsel, D. R. and T. A. Cohn. 1988. *Estimation of descriptive statistics for multiply censored water quality data*. Water Resources Research 24(12):1997-2004.
- Helsel, D. R. and R. J. Gilliom. 1986. *Estimation of distributional parameters for censored trace level water quality data: 2. Verification and applications*. Water Resources Research 22(2):147-155.
- Hinton, S. W. 1993. *A Log-normal statistical methodology performance*. Environ. Sci. Technol. 27:2247-2249.
- Lehmann, E.L. 1958. *Significance level and power*. Annals of Mathematical Statistics. 29: 1167-1176.
- Mapstone B.D. 1995. *Scalable decision rules for environmental impact studies: Effect size, type I, and type II errors*. Ecological Applications 5(2): 401-410.
- Ohio, State of. 1996. *Ohio EPA GLI issue paper. Addendum: reasonable potential*. Ohio Environmental Protection Agency. <http://www.epa.state.oh.us/dsw/gli/reaspota.pdf> August 26, 1996

- Ott, W. R. 1990. *A physical explanation of the lognormality of pollutant concentrations*. J. Air Waste Manage. Assoc. 40:1378-1383.
- SAIC. 1999. *Potential costs associated with compliance with the California Ocean Plan*. Prepared for SWRCB by Science Applications International Corporation, Reston, VA. SAIC Project No. 01-0833-00-2685-018. December 1999.
- Saiz, S. G. 2003. *RPCalc instructions and documentation*. A program to determine when effluent limitations are needed. October 14, 2003. SWRCB, Division of Water Quality, Standards Development Section, Ocean Standards Unit.
- Saiz, S.G. 2004a. *Balancing decisions-making errors when testing hypotheses with the binomial test*. Sacramento, CA, Division of Water Quality, State Water Resources Control Board. California Environmental Protection Agency.
- Saiz, S.G. 2004b. Lognormal tolerance intervals for assessing the reasonable potential to exceed water quality standards. Draft 9/21/04. Sacramento, CA, Division of Water Quality, State Water Resources Control Board. California Environmental Protection Agency.
- Shumway, R. H., R. S. Azari, and M. Kayhanian. 2002. *Statistical approaches to estimating mean water quality concentrations with detection limits*. Environ. Sci. Technol. 36(15):3345-3353.
- SWRCB. 1983. *The Final Environmental Impact Report (EIR) for the 1983 Ocean Plan* (Volume 1). State Water Resources Control Board. California Environmental Protection Agency.
- SWRCB. 2001. *California Ocean Plan*. Water Quality Control Plan for Ocean Waters of California. State Water Resources Control Board. California Environmental Protection Agency.
- SWRCB. 2004. Final Functional Equivalent Document. Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List. September 2004. State Water Resources Control Board. California Environmental Protection Agency.
- USEPA. 1991. *Technical Support Document for Water Quality-based Toxics Control*. Office of Water. EPA 5052-90-001, Second printing June 5, 1992.
- USEPA. 1992. *Statistical analysis of ground-water monitoring data at RCRA facilities. Addendum to interim final guidance*. Office of Solid Waste, Permits and State Programs Division.
<http://www.epa.gov/epaoswer/hazwaste/ca/resource/guidance/sitechar/gwstats/gwstats.htm>
- USEPA. 1995. *Final Water Quality Guidance for the Great Lakes System*. Federal Register 60 (56): 15366-15425. March 23, 1995.

USEPA. 1998. *Guidance for data quality assessment. Practical methods for data analysis.* EPA QA/G-9. QA97 Version. Office of Research and Development. EPA/600/R-96/084.